Classification to guide internal fixation for tibial fracture

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Objective: To explore a classification method which can provide the clinical guidance for internal fixation of tibial fracture.

Methods: The different fractures were fixed according to their mechanical classification. Totally, 71 cases of tibial plateau fracture, tibial proximal fracture, tibial distal fracture and Pilon fracture were analyzed to test this selective principle.

Results: All 71 patients were followed up for 6-32 months. The displacement was seldomly observed in cases treated acccording to the classification principle, while some cases against the principle had postoperative displacement. The difference was statistically significant ($P<0.05$). It was proved that there was remarkable correlation between tibial fracture classification, internal fixator and fixation methods.

Conclusion: Types IIIa3, IIIb1 and IIIb2 fractures without eccentric moment should be fixed with double plates or angle-stable materials combined with locking structure, otherwise displacement may occur.

Key words: ***Tibial fractures; Fracture fixation, internal; Classification***

Chin J Traumatol 2008; 11(6):375-379

In the treatment of orthopedic trauma, fracture in articular area is a major problem, which has high requirement for reduction quality and fixation stability. With the development of internal fixation materials, the clinicians have more choices for fixation of fractured bone in articular area. However, the complications such as displacement, collapse of articular surface, broken screws are occasionally observed. Until now, there is no practical fracture classification to provide the guidance for choosing proper fixation methods. We enrolled 71 cases of tibial fracture in articular area from June 2004 to March 2008 to investigate the relationship between fracture characteristics, fixator and fixation method.

METHODS

General data

There were 42 males and 29 females, with a mean age of 41 years (range:5-86 years). According to the classification of Association for the Study of Internal Fixation (AO), there were 33 cases of tibial proximal fracture (16 cases of type A, 9 type B and 8 type C) and 38 cases of tibial distal fracture (19 cases of type A, 12 type B and 7 type C). Twenty-three patients were fixed with angle-stable materials (including locking plate and external fixation stent), 39 with ordinary non-locking plate, 9 with screws (including absorbable screws and hollow screws) or Kirschner wire.

Clinical classification and mechanical analysis

After internal fixation of tibial fracture in articular area, the displacement and loosening or loss of screws were observed in the study. Apparently, the choice of surgical procedure and angle-stable materials are related to different types of fractures. The coding and classification committee of Orthopaedic Trauma Association (OTA) encoded the AO classification of long bone fracture. AO classification is a morphologic classification at coronal plane based on the fracture site, joint involvement, and comminutated degree, which can not give the specific guidance on the choice of fixation and angle-stable material.

This study demonstrated that with tibial backbone as axis to revolve for 360°, the mechanic characteristics of fracture bone in different sections decide the fixation, in other words, irrational fixation may cause the failure of surgery. According to fracture line, tibial fracture were classified into 3 types. The following diagram of fracture was based on the view after reduction, including coronal plane, sagittal plane and other verti-

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Chinese Journal of Traumatology 2008; 11(6):375-379

cal plane. Draw a stress line along the intersection of cortical bone and fracture line (not always be the vertical line). The angle between the stress line and fracture line was called “stable angle”. The fracture with stable angle >90° was stable (Figs.1, 2), while the fracture with stable angle<90° was unstable. Type I fracture involved single or multiple bones at bone margin: type Ia with stable angle >90° was stable, while type Ib with stable angle <90° was unstable (Figs.1, 2,13,14). Type II was single or multiple bone fracture at the center of articular surface (Figs. 3 and 15). Type III fracture involved bilateral joint area or the whole joint. Type IIIb1 had bilateral instability effecting the central part, and type IIIb2 was unstable with broken bone fragments at the center (Figs.4-8, 16-18).

Types Ia, II and IIIa1 were longitudinally and transversely stable, which can be fixed by screws. Types Ib and IIIa2 were fixed by steel plate without angle-stable material, so the plate should be placed in unstable side. Angle-stable material was used for type IIIa3 fracture without locking structure because it was transversely stable. Or it can be bilaterally fixed by plate with no angle stability. Types IIIb1 and IIIb2 were unstable longitudinally and transversely, so they should be fixed by angle-stable materials with locking structure. All mentioned above were the internal fixation guidelines in our clinical practice.

Statistical analysis

All data were processed by SPSS 8.0 statistical software package. x^2 test was used to compare the displacement rates between the cases treated acccording to the classification principle (48 cases, Group A) and the cases against the classification principle (23 cases, Group B). P<0.05 was considered statistically significant.

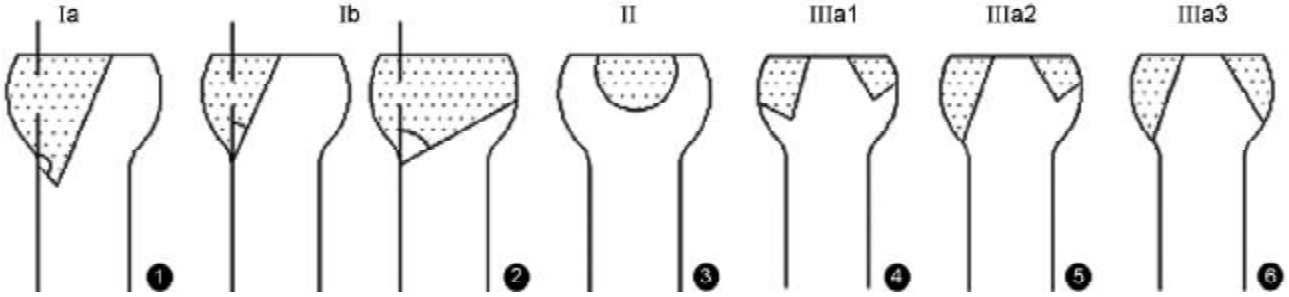

Fig.1. Type Ia fracture is longitudinally stable with stable angle >90°. **Fig.2.** Type Ib fracture is longitudinally unstable with stable angle <90°. **Fig.3.** Type II fracture is located at the center, with the edge uninjured. **Fig.4.** Type IIIa1 fracture is transversely and longitudinally stable with stable angles at both sides>90°. **Fig.5.** Type IIIa2 fracture has stable angle <90°at one side and is longitudinally stable at other side. **Fig.6.** Type IIIa3 fracture is longitudinally unstable with stable angle <90° bilaterally.

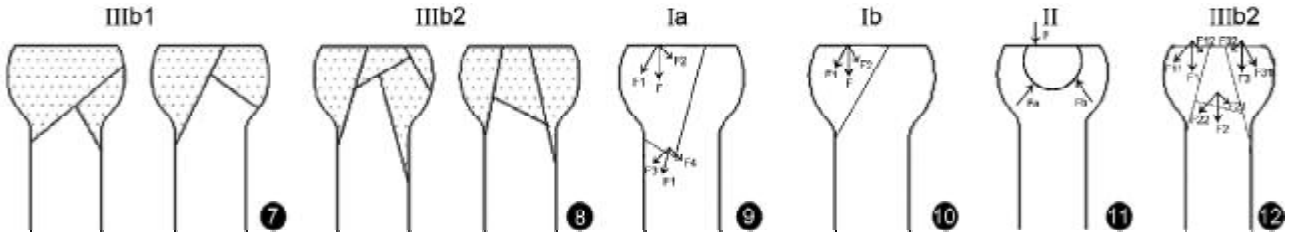

Fig.7. Type IIIb1 fracture is longitudinally unstable with the tendency of being transversely separated. **Fig.8.** Type IIIb2 fracture is transversely and longitudinally stable. Bone is injured at both sides and at the center. **Fig.9.** Stress analysis of type Ia fracture. The force F is resolved into F1 and F2; F1 is resolved into F3 and F4. **Fig.10.** Stress analysis of type Ib fracture. The component force F1 induces the displacement of bone. **Fig.11.**Stress analysis of type II fracture. Fa, Fb and F compress bone. **Fig.12.** Stress analysis of type IIIb2 fracture.The compressive forces F1, F2 and F3 produce component force F11, F21 and F31.

RESULTS

In this study, all 71 patients were surgically treated and followed up for 6-32 months. One patient with type Ib tibial plateau fracture was fixed by cancellous bone screws, but he had bone collapse later, so it was changed to steel plate. Single plates were used to reduce angular deformities in two cases of type IIIb1 tibial distal fracture. In one case of type Ib tibial plateau fracture, the joint surface collapsed in weight-bearing activity after plate fixation. No displacement was found in other cases.

Among all 71 cases, one patient had displacement in Group A (2.1%) and 5 in Group B (21.7%). x^2 test was used to compare the displacement rates between Group A and Group B (x^2=7.765, *P*=0.005). The difference was statistically significant.

Fig.13. X-ray image of type Ia fracture. **A.** before operation; **B.** after operation; **C.** 6 months after operation.

Fig.14. X-ray image of type Ib fracture. **A.** before operation; **B.** after operation; **C.** 6 months after operation.

Fig.15. X-ray image of type Ib plus type II fracture. **A.** before operation; **B.** after operation; **C.** 8 months after operation.

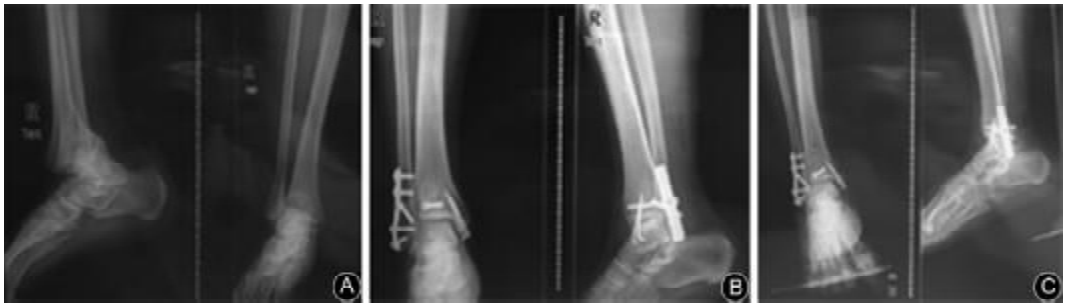

Fig.16. X-ray image of type IIIa3 fracture. **A.** before operation; **B.** after operation; **C.** 10 months after operation.

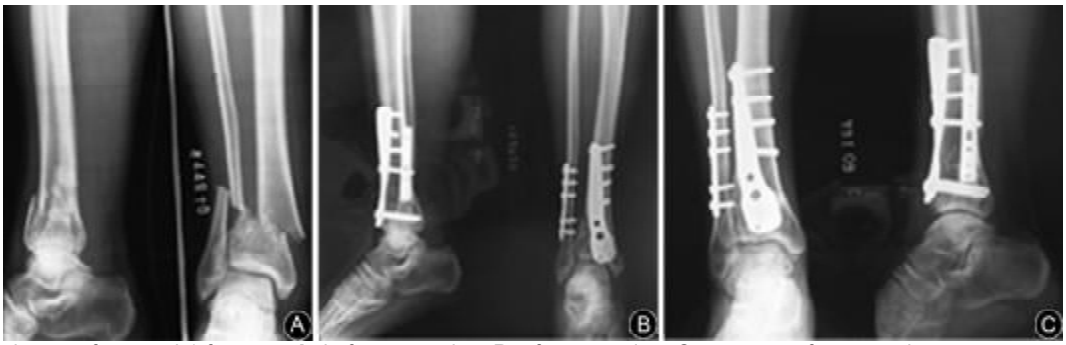

Fig.17. X-ray image of type IIIb1 fracture. **A.** before operation; **B.** after operation; **C.** one year after operation.

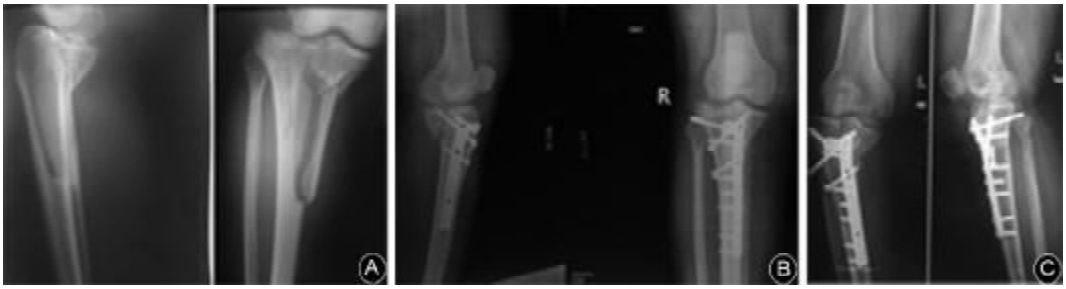

Fig.18. X-ray image of type IIIb2 fracture. **A.** before operation; **B.** after operation; **C.** genu varum appeared 8 months after operation.

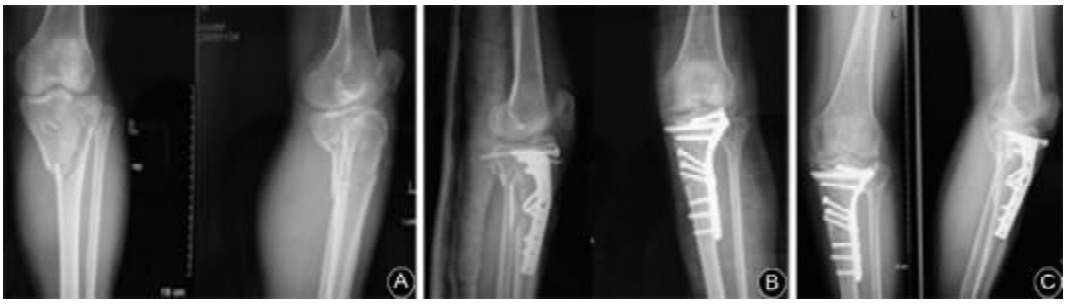

Fig.19. One case in Group A. **A:** before operation; **B:** after operation; **C:** two and half years after operation.

DISCUSSION

Angle stability refers to that the connection of bone screws with plate can maintein a certain angle under different stress. Type Ia, II and IIIa1 fractures represent the stable classification and do not dislocate even if it is fixed by screws. Type Ib and IIIa2 are laterally unstable. The force vertical to screws can decrease the control of screw to cancellous bone, causing screw loosening and displacement. So it is necessary to use supportive plate, however, angle-stable material is dispensable.

AO[2] once mentioned that single screw can not resist the compressive stress of axial deviation and twisting of metaphyseal fracture, so supportive plate should be used in that condition. Type IIIa3, which is bilaterally unstable without intereaction of both sides, should be fixed by single plate to stablize the contralateral bone, then fixed by screws or double plates. Type IIIb fracture is unstable at both sides and at the center. The angle-stable material with locking structure or double plates should be adopted because lateral non-locking plate can undertake the transverse stress rather than longitudinal stress, which may cause displacement (Fig.18). Jiang et al.[3] made a biomechanical comparison of different approaches of internal fixation for complex tibial plateau fracture (types IIIa3 and IIIb) and concluded that the stabilities of fixation by double plates, LISS plate and external fixation stent were good, while fixation by single plate was unstable, which was consistent with our results. Yang et al.[4] classified Schatzker IV tibial plateau fracture into spliting,condyle-reconstructing and collapsing subtypes (similar to type Ib), which was helpful to surgery.

The stability of reduction depends on many factors.

The displacement incidence in lower extremity is much higher than that in upper extremity because the lower extremity has more weight loading, so muscles are stronger. Sometimes, because of muscular traction, the stable type Ia fracture is changed into unstable type Ib. In this study, one case of tibial tubercle fracture belonged to type Ib according to our principle (Fig.13), but the fracture was longitudinally stable for the resistence of patellar tendon, so we considered it as type Ia. It was fixed by screws and steel wire, obtaining good outcome. The control of screw to bone can be decreased for osteoporosis. Without angle-stable material to lock the structure, screw loss and displacement could be induced. The other risk factors include operative error, weightbearing at early stage, screw dissection and off-center fixation.[5] The structures of articular surface are different at different sites, so the stress distribution is different. For example, sometimes, femoral trochanter and proximal humerus with eccentric moment were fixed with angle-stable material, but had displacement later because of its special mechanic features. We used non-angle-stable plate in the treatment of type III distal tibial fracture (Fig.17) and seldomly observed the change of anatomical position because we fixed fibula and the support from fibula made the opposite bone stable, in other words, fixed fibula became internal fixation stent and type III transformed to type Ib. In this group, displacement occurred in a case of type III tibial Pilon fracture, who received fixation of fibula fracture. One case was dislocated (Fig. 19), which can be diagnosed as type Ib from the X-ray film before operation. After postoperative exercises, articular surface collapsed because it was a complex fracture with type II. The reduced bone without bone grafting had low weight-bearing capability and induced displacement. It reminds us that CT scanning should be performed in some cases hard to be diagnosed, otherwise, some fracture type may be miss-diagnosed.

In this group, type Ib fracture, including hypocondylar fracture and medial malleolus fracture, was only fixed by screws, but no displacement occurred. The main weight-bearing parts in tibial plateau are menisci and its surrounding area. Hypocondyle and plateau margin take little stress and the weight-bearing site in tibial distal end is the corresponding area of superior articular facet of talus. The internal and external malleolus mainly take the stress of twisting, introversion and extroversion. The force on screw is not enough to dislocate it. When only screws are needed depends on the patients'weight and fractured site. Moreover, some patients are treated against our principles and the post operative X-ray film shows good prognosis, but longtime external fixation results in articular functional impairment. It demonstrated that the treatment according to our classification could lower displacement rate and facilitate functional exercises at early stage.

Our classification introduces the concept of "stable angle" based on the 3-dimensional appearance and mechanical stability of fracture. Horwitz et al.[6] thought that the instability of fixation was mainly induced by axial stress, so that vertical collapse of bone accounted for 99% of dislocation in fracture, which proved the importance of stable angle. However, there are some disadvantages such as lack of biomechanic experiment evidence, limited samples. Angle-stable materials can hold the stress vertical to screws and effectively resist axial pressure. We conclude that type IIIa3 and IIIb fractures should be fixed with angle-stable material and locking plate or double plates to prevent displacement in functional excercises or weight-bearing activities.

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(Received April 30, 2008)
Edited by LIU Jun-lan